

# Processing Benefits of Resonance Acoustic Mixing on High Performance Propellants and Explosives

Dr. Andrew Nelson and Tara Cross Presented at 2012 TTCP WPN TP-4 Panel Meeting



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**Report Documentation Page** 

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#### **Outline**

- RAM Facilities and Set-up at China Lake
- Initial RAM Energetics Evaluation
- Propellant Mixed on RAM
- Explosive Mixed on RAM



#### LabRAM





#### Resonant Acoustic Mixing of Energetic Materials at China Lake



#### **Remote Operation**







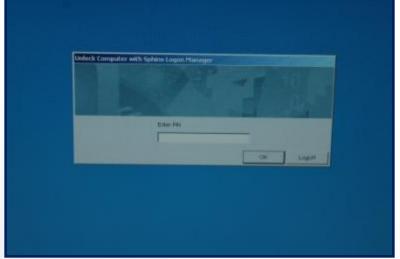


## **Computer Key Card Lockout**



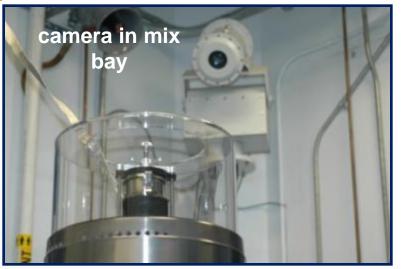








#### Remote Monitoring of Live Mix





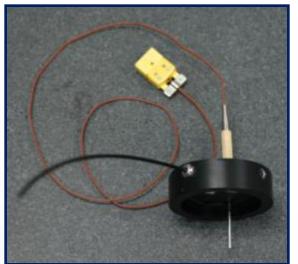


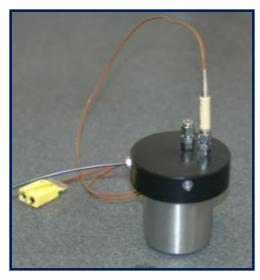


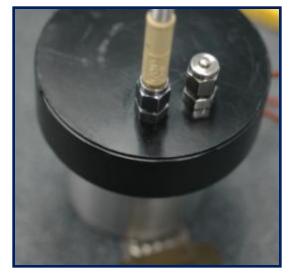




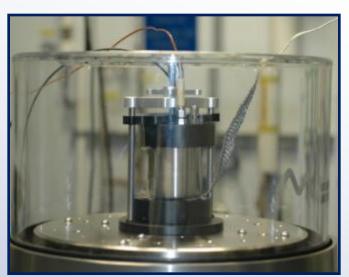
#### **Remote Temperature Monitoring**







Thermocouple lid designed by Resodyn Acoustic Mixers, Inc.









#### **General Mix Vessel Types**

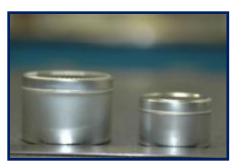








5- to 150-grams



1- to 5-grams







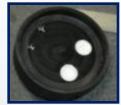




25- to 400-grams













25- to 450-grams

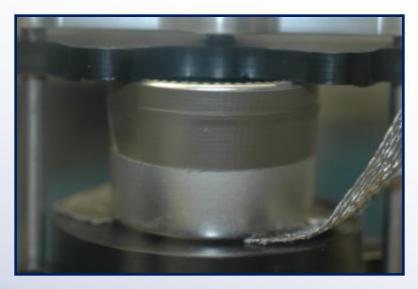
**Distribution Statement A: Approved for Public Release** 

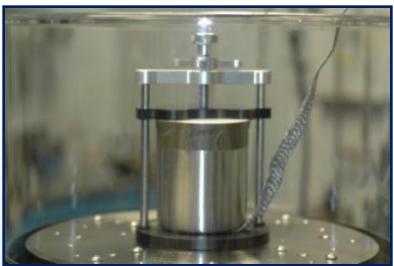


#### **Ground Mix Vessels**









**Mechanical grounding** 

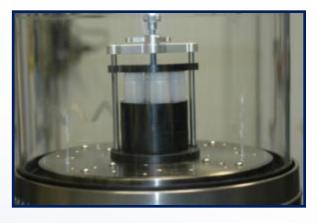


## Initial RAM Energetics Research



#### **Initial Energetic Evaluation**

- Selected Energetics
  - Polymers: GAP, PGN, PNO, BN-7
  - Plasticizers: BTTN, TMETN, TEGDN, BuNena
  - Nitramines: RDX, HMX, CL-20
- Developed mix matrix based on combinations of the energetic materials (1 from each group)
- Mix Vessel
  - Small 20-mL plastic vials
- Mix Sizes
  - 1-gram
  - 5-gram
- Mix Scheme
  - Ramped from 0% to 100% Intensity (I) using increments of 10% I
  - Held at 100% I for 10 minutes





#### Initial Energetic Evaluation

#### DSC Onsets for Energetics Mixed by Hand and RAM

Ingredients	HM DSC Onset (°C)	RAM DSC Onset (°C)	Difference (°C)
GAP-BTTN-RDX	206	203	3
GAP-BTTN-HMX	217	219	2
GAP-BTTN-CL20	202	204	2
PGN-BTTN-RDX	191	191	0
PGN-BTTN-HMX	183	186	3
PGN-BTTN-CL20	189	189	0
PNO-BTTN-RDX	184	189	5
PNO-BTTN-HMX	179	175	4
PNO-BTTN-CL20	185	185	0

**■DSC:** ambient to 350° C by ramping 5° C/min.



## Resodyn Mixed Propellant



#### **Propellant Study**

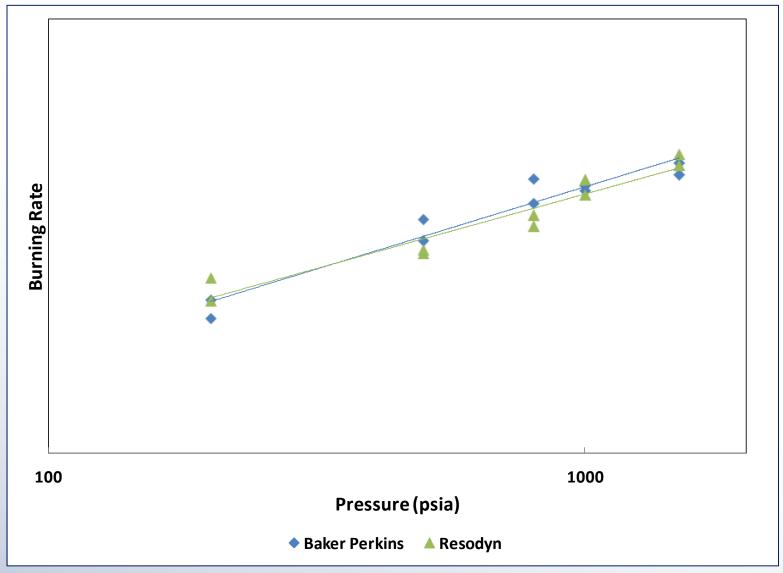
- Compare the properties of a propellant formulation mixed on the Resodyn to the same formulation mixed on the Baker Perkins
  - End of Mix Viscosity
  - Ballistic Properties
  - Tensile Properties
- Formulation
  - HTCE, AP, AI
- **RAM Mix Scheme** 
  - 125-gram mix
  - 4 mix periods, 40-50 G, total mix time 30 minutes, 78°F to 120°F
- Baker Perkins Mix Scheme
  - 125-gram mix
  - 7 mix periods, total mix time 100 minutes, 130°F
- End of Mix Viscosity
  - RAM: 21.5 kps at 95.9°F
  - BP: 7.5 kps at 120.7°F



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#### **Burning Rate Comparison**

**Burning Rates of Baker Perkins and Resodyn Mixed Propellants** 



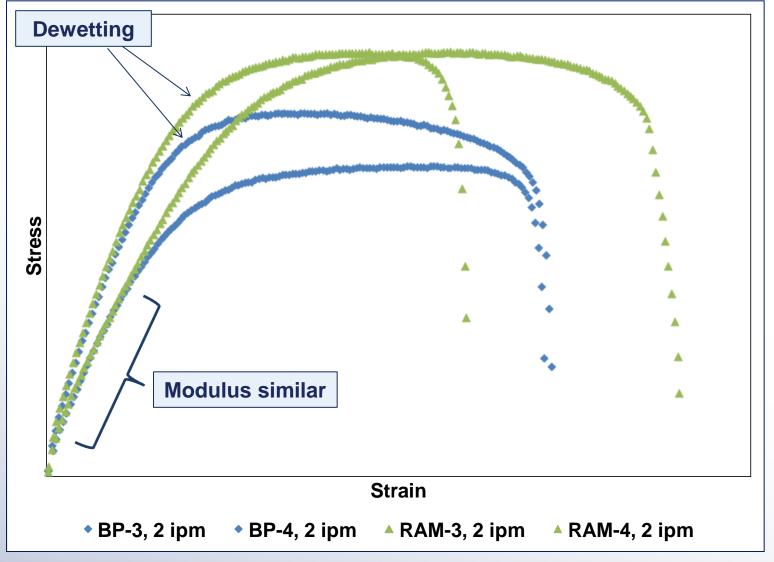
- Low pressure window bomb data
- •Burning Rates and Burning Rate Slope are similar

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#### **Tensile Comparison**

Tensile Properties of Baker Perkins and Resodyn Mixed Propellants

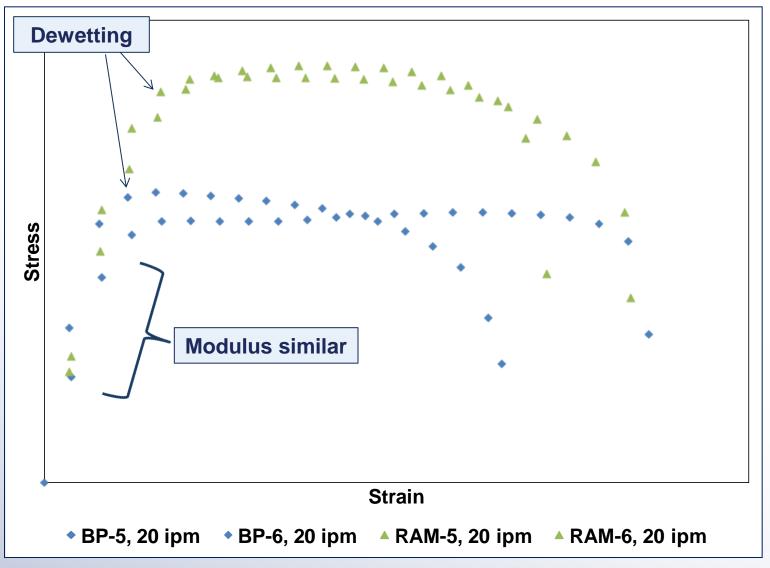


- Data from mini dogbones
- Pulled at RT and 2 in./min. cross-head speed
- RAM and BP samples show similar tensile properties
- •RAM demonstrated slightly greater stress



#### **Tensile Comparison**

#### Tensile Properties of Baker Perkins and Resodyn Mixed Propellants



- Data from mini dogbones
- •Evaluated at RT and 20 in./min. crosshead speed
- •RAM and BP samples exhibit similar tensile properties
- •RAM demonstrated greater stress

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### **Resodyn Mixed Explosive**



#### **Explosive Formulation Study**

#### Purpose

- Test the Resodyns ability to mix high viscosity materials by increasing the explosive particle surface area for a well known explosive formulation
  - Explosive particle surface area:
    - Baseline Mix: 0.021 m²/g
    - Mix A: 0.165 m<sup>2</sup>/g
    - Mix B: 1.65 m<sup>2</sup>/g

#### Motivation

- Improve solids loading to obtain higher operational performance
- Improve shock sensitivity for better IM performance
- Explosive Formulation
  - High solids filled polybutadiene binder



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Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)





Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)





Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature --125° F (2 min. after mixing is complete)

Step 3: Mixed at 75% intensity for 20 min.





- Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)
- Step 2: Mixed at 100% intensity for 60 min.; Material Temperature --125° F (2 min. after mixing is complete)
- Step 3: Mixed at 75% intensity for 20 min.
- Step 4: Mixed at 30% intensity for 10 min.





- Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)
- Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)
- Step 3: Mixed at 75% intensity for 20 min.
- Step 4: Mixed at 30% intensity for 10 min.
- Step 5: Mixed at 50% intensity for 8 min. and 20% intensity for 3 min.



#### Mix A: In-Situ Mixing and Casting: IHE GAP Tube

End of mix product -- uncured -- Top view (50% intensity for 8 min., 20% for 3 min.)





**Post Cure:** 

Top

Bottom -



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Step 1: ½ total solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

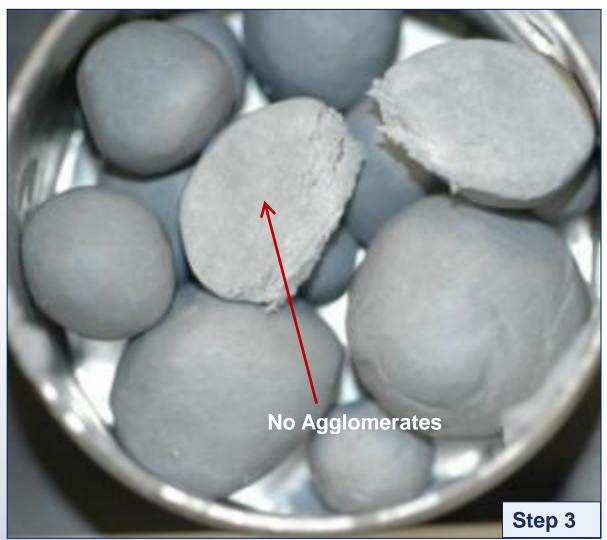




Step 1: ½ total solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed





Step 1: ½ total solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

Step 3: Mixed at 100% intensity for 60 min.; No agglomerates observed





Step 1: ½ total solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.;
Agglomerates observed

Step 3: Mixed at 100% intensity for 60 min.; No agglomerates observed

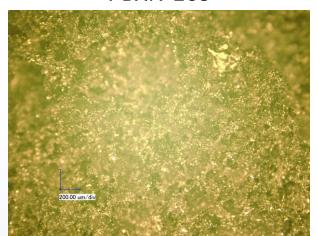
Step 4: Reduced mix vessel size;
Mixed at 50% intensity for 60
min.; No agglomerates
observed

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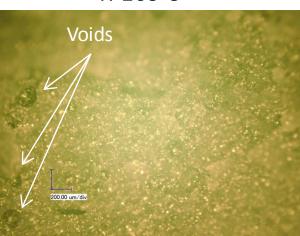


#### **Optical Microscopy**

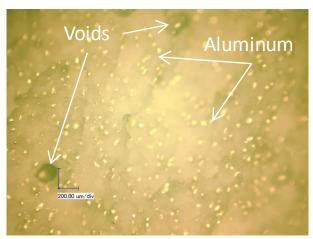
Baselipex Q\_Q21 m²/g



Mix  $A_{1} = 0.0365$  m<sup>2</sup>/g



Mix B<sub>R</sub>14.65 gm²/g



- Optical images of the broken edges of explosive
- Baseline mix was processed in a planetary mixer
- RAM mixes were not processed under vacuum
- The RAM samples appear completely homogenous with no evidence of particle agglomeration



#### Conclusions

- Initial Resodyn energetics test indicated the energetics evaluated are not adversely affected by the RAM energy input
- Propellant ballistic and tensile properties are similar for Resodyn and Baker Perkins mixes
- RAM can be used to effectively mix extremely viscous explosive formulations
  - In-situ mixing and casting is possible in small diameter test samples
- No particle agglomeration is evident in Resodyn mixed explosive



#### Acknowledgements

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- Chris Wheeler
- Heather Simons
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## Questions